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OBSERVATION ON SWIMMING AND BREATHING BEHAVIOURS OF A CAPTIVE BAIJI *Lipotes vexillifer*

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Abstract Swimming and breathing behaviours of a captive baiji *Lipotes vexillifer* were observed in a Baiji Aquarium from May to October 1992. Swimming speeds could be divided into 3 types: slow swimming (SS), middle-speed swimming (MS) and fast swimming (FS). SS was the most common swimming pattern. The average time portion of SS per hour in daytime and at night showed no significant difference, however MS's and FS's portions were obviously greater in daytime than those at night. It can be seen that baiji's movement slowed down at night was due to the lower occurred rates of MS and FS, but not increasing SS time portion. The average breathing per hour was 106.05 times (1.77 times per minute). The mean of breathing interval was 30.62 ± 24.55 s, ranging between 1.04–316 s. The respiration model of the baiji was cycles of one long interval breathing accompanying with 1-8 short interval breathings. SS's time portion per hour showed no obvious influence on breathing frequency of the baiji, but the frequency showed significant positive correlation with MS's and FS's time portions per hour. It was deduced that MS and FS would significantly increase the energy consumption by getting more air in comparison with SS.

Key words Baiji *Lipotes vexillifer*, Swimming, Breathing, Behaviour

Swimming and breathing are two most fundamental behaviours of cetacean. Swimming behaviour is the movement way of dolphins, and it is usually studied in patterns, as well as speeds for finding out the functions of different swimming patterns and the capability or intensity of dolphin's movement. On breathing, it was studied on respiration rate (the breathing frequency per unit time). The energy consumption of dolphins could also be estimated by the joint analysis between breathing and swimming behaviours. Otherwise, because the overwhelming majority of breathing intervals were the diving duration, the diving model could be understood by recording the breathings of long and short intervals (Leatherwood *et al.*, 1979; Slijper, 1979; Hui, 1987; Lockyer *et al.*, 1987).

There are few papers described about the two behaviours of baiji up to now. On swimming behaviour, most of researches were concentrated upon swimming pattern such as backstroke swimming, side swimming, rolling swimming, clockwise and counterclock-

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wise swimming (Lin *et al.*, 1985; Liu *et al.*, 1987, 1994). The diurnal rhythms of clockwise and counterclockwise swimming of baiji in captivity were also studied by Liu *et al.* (1994). Except some simple reports, there were no systematic and detailed study on the different speeds of swimming and their diurnal rhythms. About the respiration of baiji, the respiration rate, the interval of breathing, the breathing model were once reported by Chen *et al.* (1980, 1985), Liu *et al.* (1994), Zhou *et al.* (1989).

In this study, we wanted to evaluate the characteristics of the two behaviours and their rhythm of the baiji. On the other hand, the respiration model was discussed in detail and the changes of the movement intensity and energy consumption in different swimming speeds were further conjectured.

1 Animal and Methods

The baiji for this project was a male, about 15 years old individual which was caught in Chenglingji section of the Yangtze River in January 1980. Its body weight was 125 kg and body length was 2.05 m. In the study period between May and October 1992, it was healthy and reared in a circular concrete pool 7.5 m in radius and 4 m in depth. Each day 3 times of feeding were arranged between 07:00–08:00, 12:00–13:00, and 17:00–18:00.

Before formal data collection, we had determined swimming pattern of the baiji by its speed in pool. As our dolphin pool was 47.1 m in circumference, we marked a 20 m measuring section on the top of pool wall using scale of 0.1 m. Usually the baiji swam counterclockwise or clockwise along the pool wall. When it passed our measuring section, both time and distance scale in start and end recording moment were noted. From the differences division of distance and time, we could get a speed V_1. However, the baiji did not swim nestling closely to pool wall. The overwhelming majority of the distance between the dolphin and pool wall was 0.27 m, so V_1 should be amended for calculating the swimming speed (V) of the baiji in its pool and V equal 0.964 V_1. For comparing with the swimming speed of dolphin reported before, we converted all our records as km / h.

After 315 measurements, it was noticed that the frequency of the speed had an obvious increasing at 2 km / h, and had a significant decreasing at 5 km / h. So all our measurements could be including in 3 groups of $0 < V \leqslant 2$ km / h, $2 < V \leqslant 5$ km / h and $V > 5$ km / h. We defined respectively them as SS, MS and FS. In fact, when we made observation by the baiji pool, the difference of above 3 speeds could be able to feel using the displacement of our baiji in certain time, the dynamics of the baiji's fluke flicking, as well as the degree of wave produced by the animal's movement. Then, by means of these indices, we practiced on estimation of the swimming speed in several days. Before our formal study, the judgment of researcher on the baiji's speed was tested and verified, *i.e.* when baiji entered in measuring section, researcher estimated its speed as SS, MS or FS first. Later, by the calculation of V, the judgment could be tested as right or not. After there was few difference between judgment and the calculation, formal swimming speed was recorded.

During the study, We defined each of behaviour patterns on different key of a portable computer first. Then, utilizing a program written by ourselves, we could record all behavioral data by operating a computer near the pool.

Swimming and breathing behaviours were observed with resting, playing, prefeeding, sounding and sexual behaviours (the results will be presented in separate paper) in different time every day which was full of above behaviours occurring alternatively and could occupied respective time portions. Total records covered 24 hours of per day. Swimming was a state behaviour and recorded in minutes per hour. Breathing was an event behaviour and noted as times per hour. Once start order was given, time would be shown on screen of our computer immediately and changed as Beijing Time in 0.01 s precision. When a state behaviour (liking swimming) occurred, its corresponding key was pressed one time and the 'T' was marked for the pattern record in the computer. Also the start time, duration of the behaviour, as well as the end time (once another corresponding key was pressed for the other state behaviour) were stored continuously in our records. If there was a event behaviour (liking breathing) happened, we pushed on its key two times and the 'P' was marked in the record of the behaviour. Because event behaviours including breathing always took place in the process of state behavior in baiji, the records before and after event behaviour would be the same kind of state behavior. We could get the frequency of event behaviour by counting the number of 'P', but it did not influence the duration record of state behaviour.

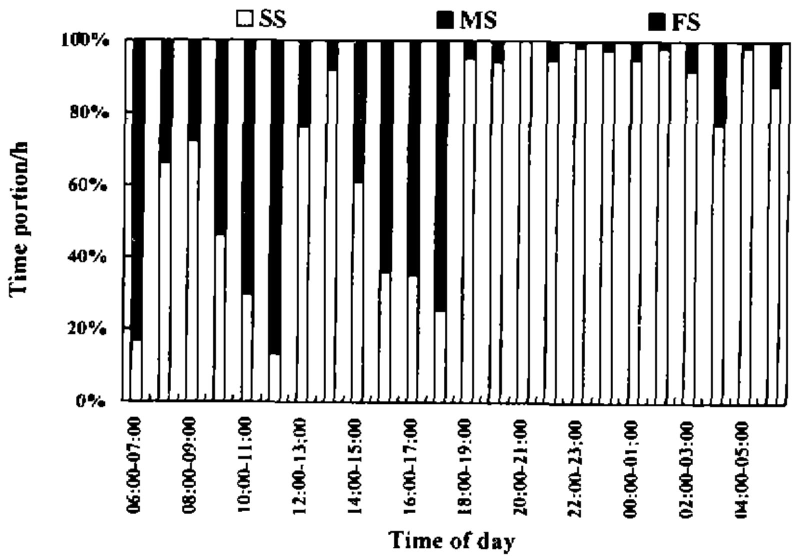

Fig. 1 Distribution of slow swimming (SS), middle-speed swimming (MS) and fast swimming (FS) in all swimming records of an adult male baiji at Baiji Aquarium

Moreover, in this work we defined long interval breathing as $t_{L1}>40$ s, t: time of breathing interval; short interval breathing as $0<t_{S1}<40$ s after a statistical analysis of 1530 breathing records. We also defined hours between 06:00—17:00 as the daytime and 17:00—06:00 as the night.

2 Results and Discussion

2.1 Swimming behaviour

2.1.1 Swimming speed A total of 315 measurements of swimming speeds were

made. The speed was 3.86±1.50 km/h, ranging between 0.26–13.44 km/h.

Lin *et al.* (1985) once made a rough determination of a calf baiji's swimming speed. The result was about 3.6 km/h. Liu *et al.* (1994) documented that the swimming speeds of baiji and the Amazon River dolphin *Inia geoffrensis* were both 1.50–3.00 km/h which were less than our results.

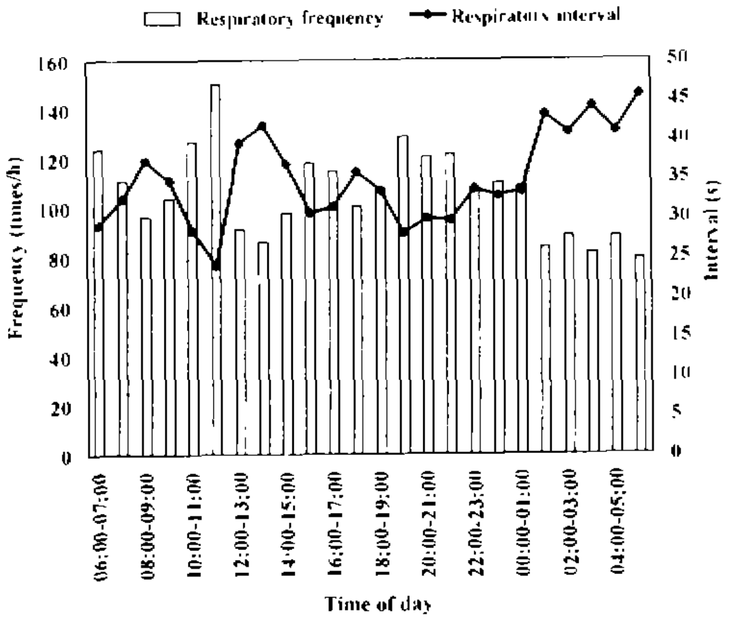

Fig. 2 Breathing in an adult male baiji at Baiji Aquarium

2.1.2 The rhythm of swimming SS, MS, FS in the dolphin took different time portions in 24 hours of a day (Fig.1). Note in particular, SS was the main pattern of swimming.

In every hour of one day, the SS portion/h was significantly and negatively correlated with the portions/h of MS ($r_{22}=-0.787$, $P<0.01$) and FS ($r_{22}=-0.548$, $P<0.01$). There was no significant difference between average SS portions in daytime and at night ($t_{22}=1.413$, $P>0.05$). However, MS and FS were significantly and positively correlated ($r_{22}=0.706$, $P<0.01$). MS portion was obviously greater in daytime than at night ($t_{22}=3.324$, $P<0.01$), and FS portions was remarkably greater in daytime than at night ($t_{22}=4.227$, $P<0.001$). Therefore, baiji's movement slowed down at night. It was not due to the increasing of SS time, but setting off by the lower occurred rates of MS and FS. By and large, the total swimming time in daytime was very significantly greater than at night ($t_{22}=3.918$, $P<0.001$).

Moving intensities were reflected on different swimming speeds. Hui (1987) studied the energy consumption of *Delphins delphis* in captivity under different swimming speeds. Result showed that their metabolic rate was 1–3 times of resting metabolic rate (RMR) when dolphins swam in average speed, so we could estimate that the energy consumption of SS was low because the speed range of SS was lower than the average speed. In Hui's study the metabolic rate would become to 13.4 times or more as dolphins swam faster. The MS and FS should be the case. Most of MS and FS were found in daytime. They made the time portion of swimming per hour increasing during

daytime. The moving intensity also increased although it would decrease in small amount after feeding time. It implied that baiji has the tendency of being a diurnal animal.

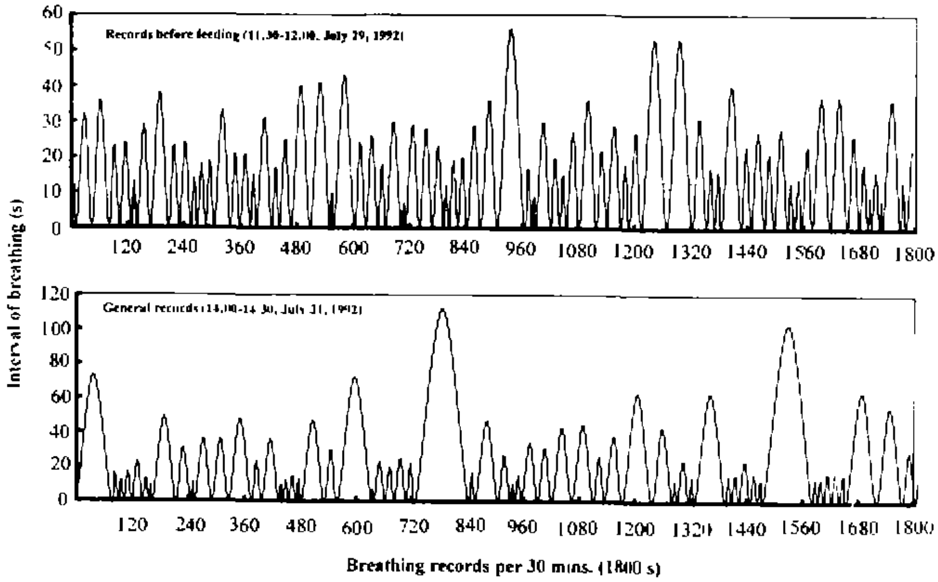

Fig 3 The model of breathing behaviour in an adult male baiji at Baiji Aquarium

2.2 Breatbing behaviour

2.2.1 The rhythm of breathing Fig.2 illustrated that the average respiratory frequency and interval time in every hour of a day. In a whole day, the average respiratory frequency was 106.05 times / h; 108.25 times / h in daytime and 103.84 times / h at night. There was no significant difference of the two frequencies ($t_{22}=0.602$, $P>0.05$). On the other hand, there were still 3 small peaks in breathing at 06:00–07:00, 11:00–12:00 and 19:00–20:00 respectively; and a small valley between 01:00–06:00. The frequency tended to decrease after feeding in day time and at night.

The average respiratory frequency of Amazon River dolphin was 115.02 times / h (1.92 times / min.) for the female and 84.11 times / h (1.40 times / min.) for the male (Tobayama *et al.*, 1989) or 36–60 times / h (0.60–1.00 times / min.) in general (Liu *et al.*, 1994). It was about 88.08 times / h (1.47 times / min.) for Ganges River dolphin *Platanista gangetica* (Pilleri, 1970) and 40.20–79.80 times / h(0.67–1.33 times / min.) for Indus River dolphin *Platanista minor* (Pilleri *et al.*, 1971). In our study, it was 106.05 times / h (1.77 times / min.) for baiji. We concluded that the average respiratory frequency of freshwater dolphins was probably below 120 times / h (2 times / min.).

2.2.2 The model of breathing After counting the 1530 breathings of 14 continued records, we found that the average breathing interval was 30.62 ± 24.55 s and it showed no distinct difference between in daytime (34.28 ± 6.18 s) and at night (35.42 ± 5.49 s) ($t_{22}=0.479$, $P>0.05$).

Chen *et al.* (1985) reported that the average breathing interval of the baiji in the Yangtze River was 25.31 s in daytime and 51.28 s at night. The interval at night was obviously longer than in daytime. These results were very different with our observations in

captivity. We thought that the difference might bring about by the different time of observation. The result in this paper was calculated from 24 h monitoring in a whole day, but it is impossible to do so in the Yangtze River up to now. It is believed that further investigations on the breathing rhythm of baiji in wild are needed by means of more advanced techniques such as radiotelemetry.

The breathing interval range of our work was 1.04–316 s which was much longer than the ranges of 5–135 s (Chen *et al.*, 1980; Liu *et al.*, 1994) and 4–145 s (Zhou *et al.*,1989) reported before in the Yangtze River. This meant that baiji was able to stay under water surface for more than 5 minutes which was much longer than former reported results.

All 1530 records could also be divided into 284 integrated breathing groups in which a long interval breathing (average interval was 64.67 ± 29.66 s, $N=296$) usually followed by 1–8 short interval breathings (average interval was 20.91 ± 8.63 s, $N=685$). In a few cases, a long interval breathing was followed by another and the number of followed short breathing would increase 3–5 times before feeding periods (Fig.3).

The breathing model of baiji is well in keeping with Slijper's (1979) observation on whales and dolphins and Zhou *et al.* (1989) reported on wild baiji. The most likely explanation was that whales and dolphins anticipated long dives in short interval breathings and took up enoughoxygen to prevent them from depleting their oxygen reserve and having to recuperate afterwards (Kastelein *et al.*, 1991). In long diving, they could have more time to feed, play, rest and so on.

The correlation examination between the frequency of respiratory / h and the time portions of SS / h, MS / h and FS / h showed that the frequency of breathing did not raise with SS portion / h obviously ($r_{22}=-0.260$, $P>0.05$). However, the frequency increasing with the time portions of MS / h ($r_{22}=0.510$, $P<0.05$) and FS / h ($r_{22}=0.454$, $P<0.05$), indicates MS and FS significantly increasing the energy consumption because the lungs of whales and dolphins are already filled to capacity , can get more air only by increasing the frequency of respiration (Slijper, 1979).

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389-395

饲养条件下白鱀豚的游动及呼吸行为观察

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摘要　1992年5月到10月，我们对养于中国科学院水生生物研究所白鱀豚馆的1头白鱀豚进行了游动和呼吸及其昼夜节律的研究。根据游速测定将其游动分为慢速游、中速游和快速游3类。慢速游为最基本的游动方式，其1天中每小时所占的时间份额无明显的昼夜差异，而中、快速游则白天显著多于夜晚；因此，我们所观察到的白鱀豚夜晚运动减缓的节律是中、快速游减少的结果。白鱀豚1天中平均呼吸频率为106.05次／h（1.77次／min）。其平均呼吸间隔时间为30.62±24.55 s，范围1.04—316 s。白鱀豚的呼吸模式为1次长间隔呼吸之后伴随1—8次短间隔呼吸。慢速游不会明显提高白鱀豚的呼吸频率，而中、快速游将使呼吸频率显著提高，反映出中、快速游会使白鱀豚的能耗显著增加。

关键词　白鱀豚，游动，呼吸，行为

饲养